ARMY RESEARCH LABORATORY

Ultra Wideband (UWB) Synchronous Impulse Reconstruction (SIRE) Radar Upgrade Assessment Field Experiment

by Brian Stanton, Francois Koenig, Greg Mazzaro, Marc Ressler, Kelly Sherbondy, and Gregory Smith

ARL-TR-5531 **April 2011**

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Sensors and Electron Devices Directorate, ARL

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
April 2011		April 2011

4. TITLE AND SUBTITLE

Ultra Wideband (UWB) Synchronous Impulse Reconstruction (SIRE) Radar Upgrade Assessment Field Experiment

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Brian Stanton, Francois Koenig, Greg Mazzaro, Marc Ressler, Kelly Sherbondy, and Gregory Smith

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Research Laboratory
ATTN: RDRL-SER-U
2800 Powder Mill Road
Adelphi MD 20783-1197

8. PERFORMING ORGANIZATION REPORT NUMBER

ARL-TR-5531

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Several upgrades have been incorporated into the Ultra Wideband (UWB) Synchronous Impulse Reconstruction (SIRE) radar, which includes (a) Augmented Reality, (b) antenna array mounting structure, (c) electronic switch and electro-mechanical relay, and (d) low noise amplifiers. The purpose of the experiment is to assess UWB SIRE radar upgrades.

15. SUBJECT TERMS

UWB, radar, augmented reality

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Brian Stanton
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	32	19b. TELEPHONE NUMBER (*Include area code*) (301) 394-0855

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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Summary

The U.S. Army Research Laboratory (ARL) Sensors & Electron Devices Directorate (SEDD), Radio Frequency (RF) Signal Processing and Modeling Branch designed, developed, and fabricated a second-generation Ultra Wideband (UWB) Synthetic Aperture Radar (SAR) to investigate the feasibility of using UWB radar technology for (a) autonomous robotic vehicle navigation; (b) detecting landmines, Improvised Explosive Devices (IEDs), and unexploded ordnance (UXO) placed on the surface and buried underground; (c) detecting tactical vehicles concealed in foliage; and (d) sensing through the wall. This second-generation radar is referred to as the ARL UWB Synchronous Impulse Reconstruction (SIRE) radar. The UWB SIRE radar is installed in a Ford Expedition. The Expedition provides (a) sufficient cargo space for integrating the UWB SIRE radar and support equipment, (b) suitable ground clearance and power to traverse difficult and rugged terrain, (c) rigid roof structure with adequate height and width for mounting an array of antennas, (d) adequate space to add batteries for powering UWB SIRE radar and support equipment, and (e) passenger seating for at least two team members with UWB SIRE radar equipment installed.

Several upgrades have been incorporated into the UWB SIRE radar, which include (a) Augmented Reality, (b) antenna array mounting structure, (c) electronic switch and electro-mechanical relay, and (d) low noise amplifiers and filters.

The purpose of the experiment is to assess UWB SIRE radar upgrades.

The UWB SIRE radar upgrade assessment will be conducted in two phases. Personnel from the RF Signal Processing and Modeling branch will conduct all phases of this field experiment unless otherwise noted.

Phase I consists of system checkouts, verifications, and validations. The intent of this phase is to identify any existing equipment failures prior to the start of assessing the UWB SIRE radar upgrades. Checkouts will initially be conducted on individual systems. After each radar sub-system has successfully passed checkout, the systems will be integrated into the UWB SIRE radar. Data will be collected on a simple target set arrangement using 42 cm trihedrals. Phase II consists of placing the target set arrangement, targets, data collection, data analysis, and image formation.

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1. Background

The U.S. Army Research Laboratory (ARL), Adelphi, Sensors & Electron Devices Directorate (SEDD), Radio Frequency (RF) Signal Processing and Modeling branch designed, developed, and fabricated a second-generation Ultra Wideband (UWB) Synthetic Aperture Radar (SAR) to investigate the feasibility of using UWB radar technology for (a) autonomous robotic vehicle navigation, (b) detecting landmines, Improvised Explosive Devices (IEDs), and unexploded ordnance (UXO) placed on the surface and buried underground, (c) detecting tactical vehicles concealed in foliage, and (d) sensing through the wall. This second generation radar is referred to as the ARL UWB Synchronous Impulse Reconstruction (SIRE) radar. The UWB SIRE radar is installed in a Ford Expedition. The Expedition provides (a) sufficient cargo space for integrating the UWB SIRE radar and support equipment, (b) suitable ground clearance and power to traverse difficult and rugged terrain, (c) rigid roof structure with adequate height and width for mounting an array of antennas, (d) adequate space to add batteries for powering UWB SIRE radar and support equipment, and (e) passenger seating for at least two team members with UWB SIRE radar equipment installed.

Several upgrades are incorporated into the UWB SIRE radar, which includes (a) Augmented Reality, (b) an antenna array mounting structure, (c) an electronic switch and electro-mechanical relay, and (d) low noise amplifiers.

The Augmented Reality system provides the user with a digital representation of the surrounding radar real-world environment. The digital representation is accomplished by superimposing both UWB radar and satellite map imagery onto commercial-off-the-shelf (COTS) digital video camera imagery. Camera position information is provided by a Differential Global Positioning System (DGPS)/Inertial Navigation System (INS) system.

ARL recently designed and built an antenna array mounting structure that provides personnel with (a) a safe electro-mechanical method for lifting the antenna array (weight ~500 lbs) to three known operational height positions: 0 or flush with roof, 0.5 m height above roof, and 1.0 m height above the roof structure of the SUV; (b) a method for changing the antenna array mounting structure depression angles between 0, 5, 10, 15, 20, 25, and 30°; and (c) a turntable capability such that the antenna array can be maneuvered to various orientations: forward-looking at 0°, left and right side-looking at angles of ±45° and ±90°.

The RF electronic switch was incorporated to address pulse ringing caused by an impedance mismatch apparent in the transmitter-antennas. This high-speed switch passes the desired radar pulse from transmitter to antenna and dissipates undesired reflections in a matched load. The RF electro-mechanical relay was incorporated to address amplitude and timing imbalances between

the two transmitter-antenna pairs. The relay eliminates the imbalance by switching a single transmitter between two antennas.

Low noise amplifiers and filters were added to each of the 16 receive channels with the intent of increasing the received signal-to-noise ratio in the frequency bands where the radar is operating.

2. Purpose of Experiment

The purpose of the experiment is to assess UWB SIRE radar upgrades.

3. Description of UWB SIRE Radar

3.1 Basic UWB SIRE Radar

The UWB SIRE radar was designed using COTS components in an effort to make the system affordable and scalable. A modular design approach was used so that modifications could be easily implemented. The SIRE system has 16 receive channels housed in a Versa Module Europa (VME) eight-slot, 6U form factor chassis. Four receive channels are located on a single circuit board. Each receive channel consists of a track and hold (T/H) assembly, analog-to-digital (A/D) converter, with a field programmable gate array (FPGA) to pull the data off the A/D converters, and integrate and reconstruct the waveforms. The eight-slot VME chassis dedicates four slots to the 16-channel receiver, one slot to the timing and control, and one slot for the interface control board (FPGA Master Controller); two slots are spares for future growth. The radar has a single transmitter, but two transmit antennas are located on opposite ends of the receive antenna array. The UWB radar is controlled by a Dell Workstation (WS) 670 Personal Computer (PC). The UWB SIRE radar was designed to accommodate vehicle speeds of approximately 2.2 mph. Pertinent operating parameters of the UWB SIRE radar are provided in table 1.

Table 1. ARL UWB SIRE radar parameters.

Receive Antenna Array	16 Vivaldi Notch Antennas
Transmit Antennas	2 TEM Horns
Frequency Coverage	300–2200 MHz
PRF	1 MHz (effective ~3 Hz)
Down Range Survey Detection Area	8 m–33 m
Polarization	HH or VV
Waveform	Impulse
Receiver Noise Floor/Loss	~2 dB / ~2 dB
Processed Range Gates	1250
Range Gate Size	~2 cm
Number of Pulses sampled/range gate	1024
Data Archiving	Summed and interleaved
2D and 3D Imaging	Yes
Augmented Reality	Digital representation of surrounding environment

4. Scope of Experiment

The UWB SIRE radar upgrade assessment field experiment will be conducted at a host activity. The targets and target set arrangement will be defined, obtained, and placed by ARL personnel. Targets will be digitally documented real-time as part of the field experiment data collection. Photographic images will be taken of each target by authorized host activity personnel. Target locations will be GPS-surveyed by host activity personnel. If needed for troubleshooting purposes, ARL personnel will monitor and record the ambient electromagnetic environment (EME), and identify sources of interference using a spectrum analyzer and appropriate antenna.

4.1 Experiment and Experiment Conditions

The UWB SIRE radar upgrade assessment will be conducted in two phases. Personnel from the RF Signal Processing and Modeling branch will conduct all phases of this field experiment unless otherwise noted.

4.2 Experiment Configurations

The UWB SIRE radar will be in a ready configuration. Ready configuration is defined as the state in which the Expedition, radar hardware and software, support equipment, and Augmented Reality are operational and have been functionally checked. During this experiment, UWB SIRE radar safety and handling will conform to the Risk Management section of this experiment plan.

4.3 Limitations to Scope

If the UWB SIRE radar, Ford Expedition, DGPS/INS, camera, Augmented Reality, or data processing computer operation becomes degraded, a determination will be made to proceed or halt the field experiment until the degraded unit can be repaired or replaced.

5. Procedures and Methodology

Phase I

5.1 Radar System Checkout/Verification/Validation

Phase I consists of system checkouts, verifications, and validations. The intent of this phase is to identify any existing equipment failures prior to the start of assessing the UWB SIRE radar upgrades. Checkouts will initially be conducted on individual systems. After each radar sub-system has successfully passed checkout, the systems will be integrated into the UWB SIRE radar. Data will be collected on a simple target set arrangement using 42-cm trihedrals.

5.2 Ford Expedition

A functional checkout will be conducted on the vehicle prior to the start of the field experiment to ensure proper operation. The radar does need not to be installed for the checkout. Approximately 1 h will be required at ARL to complete the functional checkout.

The vehicle will be inspected for leaks and worn or damaged belts. Radiator, transmission, brake, and window washer fluids will be topped off. The tires will be checked for proper pressure and air will be added if necessary. External lights (brake lights, turning signals, head lamps, and running lights) will be turned on and checked. Burned-out bulbs will be replaced. The electrical system, air-conditioning, and rain removal system will be checked to ensure proper operation. If a minor mechanical failure is discovered during the functional check, team members will determine if the problem requires repair prior to the start of the field experiment. If the failure has a minimal impact on crew safety and/or the experiment, the problem will be documented and the field experiment will begin. If the failure compromises crew safety and/or impacts the experiment, maintenance personnel will be notified, and arrangements will be made to have the item repaired prior to the experiment.

5.3 DGPS/INS

A functional checkout of the DGPS/INS system will be conducted to verify that real-time position, time, and velocity measurements are provided. Approximately 5 h will be required at ARL to complete this test.

The DGPS/INS will be evaluated to verify that real-time position, time, and velocity measurements from the INS are updated by the DGPS. The system will be powered ON, and the

self-test result will be observed. The base station will be located at the same position for the duration of the field experiment. The position will be marked via spray paint or wood stake to provide a visual reference. The GPS system will be operated for a minimum duration of 3 h with each battery to verify (a) adequate battery life for data runs; (b) that a minimum of four satellite signals are being received; (c) that a minimum of four receiver channels are operational; (d) that the position, time, and velocity are being derived; (e) data can be stored, (f) that the system responds to commands from the Dell WS670 PC and control system software; (g) that the acquisition data software receives and writes the DGPS/INS data stream to the proper file; and (h) that recorded DGPS/INS data from both the base and rover receivers can be post processed. Batteries that discharge in less than 1 h will not be used during the experiment.

5.4 UWB SIRE Radar

The UWB SIRE radar checkout will be conducted to verify proper hardware and software operation (transmitter, receiver, data acquisition, control system software). Approximately 8 h will be required at the host activity to assemble the various UWB SIRE radar components and complete the system checkout.

A system end-to-end check will be conducted to verify that the UWB SIRE radar is fully functional. The radar will be installed in the Ford Expedition, which will remain stationary for the checkout. The UWB SIRE radar and support equipment will be evaluated using the Built-In Test (BIT). BIT will be used to evaluate and verify proper operation of the (a) transmitter, (b) receiver front end (each channel), (c) RFI sniff mode, (d) DGPS/INS receiver, (e) Dell WS 670 PC, (f) data acquisition software, (g) control system software, and (h) DGPS/INS data stream recording. The Dell WS670 PC, in conjunction with the control system software and BIT, will be used to observe and test the transmitter, receiver channels, GPS, RFI sniff mode, and data recording.

The transmitter waveforms will be visually observed real-time and recorded via BIT mode. BIT mode will be used to observe the waveforms real-time, in both the frequency domain and time domain.

The receiver front end and RFI sniff mode will be evaluated by comparing the return signals from a 42-cm trihedral for each channel. The return signals from each channel will be captured, plotted, and compared to each other. A channel will be considered degraded if (a) there is an amplitude variation of more than 6 dB at a particular frequency or time compared to the other channels, or (b) there is a frequency variation of more than 50 MHz (or 20 ns) at a particular amplitude compared to the other channels. The Quad receiver card containing the degraded channel will be removed and replaced with a spare Quad receiver card.

5.5 Functional Calibration

A functional calibration will be conducted prior to the start of the field experiment. The functional calibration will be conducted to determine the amplitude variation and time delays

between the receive channels. A single 42-cm trihedral elevated 2.0 m above ground level (AGL) using Styrofoam will be used to determine the receive channel delays with both the transmitter and receiver antennas. The functional calibration will be conducted in conjunction with the UWB SIRE radar checkout. Approximately 1 h will be needed at the host activity to collect and process data.

The 42-cm trihedral will be elevated 2 m AGL using Styrofoam and will be placed 15 m downrange from the radar. The trihedral location will be GPS-surveyed. The functional calibration will be conducted with the Ford Expedition inline of the elevated trihedral. The vehicle will remain stationary while the UWB SIRE radar transmits and receives in Horizontal receive and Horizontal transmit antenna (HH) polarization for approximately 2 min. The trihedral and Styrofoam will be removed so background data can be collected. The vehicle will again remain stationary while the UWB SIRE radar transmits and receives for approximately 2 min. These procedures will be repeated while the UWB SIRE radar transmits and receives in Vertical receive and Vertical transmit antenna (VV) polarization. The data will be used to determine the amplitude variations and time delays between the individual receive channels.

Phase II

5.6 Field Experiments

Phase II consists of placing the target set arrangement, targets, data collection, data analysis, and image formation.

5.6.1 Target Set Arrangement Setup

A target set arrangement consisting of seven 42 cm trihedrals will be used to collect data and assess the upgrades. The trihedrals' locations will be GPS-surveyed and digitally documented. Approximately 2 h will be required at the host activity to place the target set arrangement, complete GPS surveys, and digitally document the arrangement.

5.6.2 Soil Characterization

The soil will be electrically characterized at locations where the trihedrals are placed prior to the start of the first data run using the newly developed ring resonator. Approximately 0.5 h will be required at the host activity to collect the soil data.

5.6.3 Target Set Arrangement

Phase II will consist of placing seven 42-cm trihedrals along a 1000-m lane of graded indigenous soil. The trihedrals will be placed on the side and off-center of the lane for forward-looking mode, as shown in figure 1; the Δ represents a trihedral. The trihedrals will be tilted forward approximately 37° to obtain the optimum radar response. The target set arrangement will be documented via GPS survey, digital photos, and video. The trihedrals will be placed outboard of

the lane approximately 10 m for side-looking mode, but will remain at the same distance downrange.

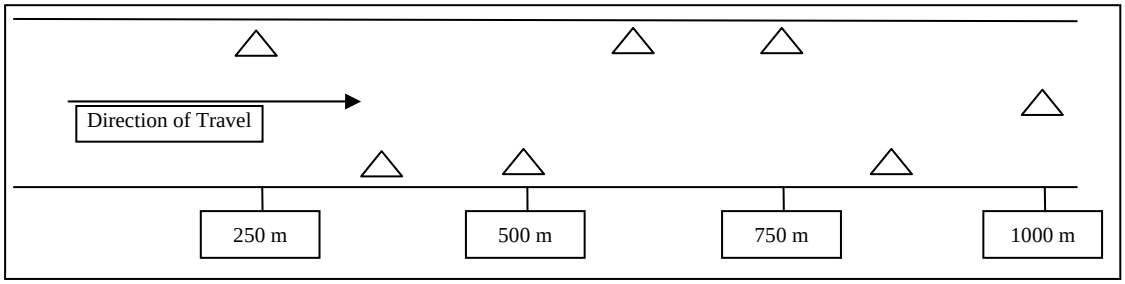

Figure 1. UWB SIRE radar upgrade assessment target set arrangement.

5.6.4 UWB SIRE Radar Data Collection and Data Analysis

Trihedral backscatter data will be collected using the UWB SIRE radar with the intent of assessing the upgrades. Data will be collected with the antenna array assembly at a 1 m height in forward-looking and side-looking modes, with both HH polarization and VV polarization. Two data runs will be made per radar configuration. Radar imagery will be formed on-site and provided to the Augmented Reality system. Approximately 33.5 h will be required at the host activity to collect and analyze the data.

5.6.5 Data Runs

The Ford Expedition UWB SIRE radar will travel through the target set arrangement at a speed of approximately 2 mph. The data runs will be initiated with the Ford Expedition located at the beginning of the lane. The UWB SIRE radar will be continuously transmitting and receiving while the Ford Expedition is driven through the target set arrangement. When the Expedition reaches the end of the target set arrangement, the UWB SIRE radar transmissions will be discontinued.

5.6.6 Upgrade Assessment Priorities

The prioritized events and summary of time to complete phase II are contained in table 2.

Table 2. Prioritized Phase II events and anticipated time.

Priority	Event	Time (Hours)
1	Radar set-up and checkout.	8.0
2	Placement of target set arrangement.	1.0
3	GPS survey, digital documentation, and soil measurements.	1.5
4	Data collection forward-looking, VV polarization.	1.0
5	Convert from VV polarization to HH polarization.	0.5
6	Data collection forward-looking, HH polarization.	1.0
7	Convert from forward-looking to side-looking.	0.5
8	Data collection side-looking, HH polarization.	1.0
9	Convert from HH polarization to VV polarization.	0.5
10	Data collection side-looking, VV polarization.	1.0
11	Data Analysis (3 hrs/1000 m data run x 8 data runs).	24.0
12	Augmented Reality data run (2.0 hrs/look configuration x 2 configurations).	4.0
13	Radar break-down and pack-up.	4.0
14	Trihedral retrieval.	0.5
	Total Time	48.5

6. Support Requirements

Table 3 lists requested host activity support necessary to accomplish the field experiment. Table 4 contains the coordination action items ARL personnel will address prior to the field experiment. An Experiment Readiness Review (ERR) will be conducted approximately 1 week prior to the start of the field experiment to review all support requirements.

6.1 Host Activity Support Requirements

Table 3 lists various host activity support activities and corresponding responsibilities necessary to accomplish the field experiment.

Table 3. Requested host activity support.

Responsibility	Requested Support
Host Activity	**Infrastructure** Provide access to staging area and experiment site. Provide space for assembling/disassembling/troubleshooting UWB SIRE Radar. Coordinate badge access to ranges.
Host Activity	**Host Activity Day to Day Liaison** Identify liaison for day-to-day coordination activities. Provide address for shipping UWB SIRE radar hardware. Provide location for staging prior to field experiment start.
Host Activity	**Frequency Authorization** Provide guidance when needed. Process spectrum management request.
Host Activity	**Safety** Provide guidance when needed. Review and approve safety items.
Host Activity	**Range Access** Provide range safety course training. Supply handheld radios while on range.
Host Activity	**Target Set Arrangement** Authorize requested test locations. Document via video and photographs. Complete GPS target location surveys.

6.2 ARL Coordination Activities

Table 4 lists various ARL coordination activities and corresponding responsibilities necessary to accomplish the field experiment.

Table 4. ARL coordination action items.

Responsibility	Coordination
ARL	**Infrastructure** Provide list of experiment personnel needing access to host activity range.
ARL	**Host Activity Day to Day Liaison** Contact host activity liaison at least once per week.
ARL	**Frequency Authorization** Coordinate with host activity spectrum management (SM). Submit required forms and documentation to SM.
ARL	**Safety** Follow special precautions outlined in this experiment plan. Follow host activity safety procedures and protocols. Submit Communications-Electronics Research, Developmkent, and Engineering Center (CERDEC) Safety checklist.
ARL	**Range Access** Provide list of personnel needing range training.
ARL	**Target Set Arrangement** Provide targets.

7. Risk Management

During the field experiment, only RDRL-SER-U personnel will operate the UWB SIRE radar. ARL will submit the CERDEC Safety Checklist at least 2 weeks prior to the start of the field experiment.

7.1 Hazard Analysis

The Hazard Analysis is provided in appendix A.

7.2 UWB SIRE Radar Hazard Area

Since the UWB SIRE radar operates across a wide range of frequencies, there is no single value for the Maximum Permissible Exposure (MPE). As recommended, the FCC MPE, reference 1, to personnel from RF was calculated from 300 MHz to 2300 MHz in 100 MHz increments. The FCC defines an operational/controlled environment as a situation in which persons are exposed as a consequence of their employment, provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled environments also apply in situations where an individual is transient through a location where occupational/controlled limits apply, provided he or she is made aware of the potential exposure. Exposure is measured as the average power accumulated in a 6-min period. The FCC defines general population/uncontrolled exposures as situations in which the general public may be exposed, or in which persons who are exposed as a consequence of their employment may not be fully aware of the potential for exposure, or who cannot exercise control over their exposure. For this measurement, the average is carried out over a 30-min period.

7.3 UWB SIRE Radar Calculations

The transmitter has a peak power of 6.25 W and an average transmit power of 5 mW across the entire frequency band fed to a transverse electromagnetic (TEM) horn with an area of 142 cm^2. The estimated power density at the face of an antenna is 0.14 mW/cm^2, which is below the most stringent occupational, as well as general public MPE limits. As a further check of compliance, a curve was fitted to the output spectrum measured from one of the transmitters, and the power available in 100 MHz bands was calculated along with a gain for an aperture antenna whose effective aperture (A_e) is 0.0071 m^2, this being an equivalent size of one of the TEM horns. A comparison of this FCC approach to antenna gain versus our measured gain shows a close match. The power density does not exceed the FCC MPE operational/controlled limit or population/uncontrolled limit at any frequency. Table 5 shows the maximum MPE limits and UWB SIRE radar field power density for each frequency, as well as the safety range at that frequency. The ranges are all much less than the far field or even transition region, and are, therefore, in the reactive near field of the antenna and expected to be overly cautious. The

ranges, however, are on the order of a millimeter, and being this close, the question would arise as to whether Permissible Exposure Limit (PEL) limits are a reasonable approach for this safety evaluation, as the FCC uses specific absorption rate for handheld and portable devices that are less than 20 cm from the body. While the total power at the face of the antenna is still below PEL limits, it would be prudent to stay at least that distance (~7.8 in) away from the front of the antennas for extended periods of time in case "hot spots" might be present in the reactive near field of the antenna. Realize that there is an additional safety factor of two when one is near one of the antennas, as it only operates ~50% of the time. As can be seen, the UWB SIRE radar is not a safety hazard to personnel or the general population.

Table 5. UWB SIRE radar maximum power densities and FCC MPE limits.

Frequency (MHz)	**Fractional Peak Power (W)**	**MPE Limit (mW/cm^2) (controlled)**	**Safe Range to controlled MPE Limit (m)**	**Safe Range to uncontrolled MPE Limit (m)**
300	0.110	1.0000	0.0003	0.0006
400	0.192	1.3333	0.0004	0.0010
500	0.290	1.6667	0.0006	0.0013
600	0.389	2.0000	0.0007	0.0017
700	0.477	2.3333	0.0009	0.0020
800	0.547	2.6667	0.0010	0.0023
900	0.594	3.0000	0.0011	0.0025
1000	0.613	3.3333	0.0012	0.0027
1100	0.605	3.6667	0.0013	0.0028
1200	0.568	4.0000	0.0013	0.0028
1300	0.506	4.3333	0.0012	0.0028
1400	0.425	4.6667	0.0012	0.0027
1500	0.334	5.0000	0.0011	0.0024
1600	0.244	5.0000	0.0010	0.0022
1700	0.165	5.0000	0.0009	0.0019
1800	0.103	5.0000	0.0007	0.0016
1900	0.059	5.0000	0.0006	0.0013
2000	0.032	5.0000	0.0004	0.0010
2100	0.016	5.0000	0.0003	0.0007
2200	0.008	5.0000	0.0002	0.0005
2300	0.004	5.0000	0.0002	0.0004

7.4 Safe Separation Distance for Munitions

The safe separation distance for unshielded munitions was calculated to be 31.35 ft using equation 2, per reference 2. The most offensive combination of gain/transmit power was used for the calculations, which occurs at 900 MHz. Reference 2 recommends using the average power if the pulse width is less than 10 ms. The UWB SIRE radar has a 1.1 ns pulse width; however, the peak transmit power was used in lieu of the average transmit power to provide an additional safety margin.

$$D = \frac{7137}{F}\sqrt{P_t * G_t}, \quad (2)$$

where, D = Distance in feet

F = Frequency in MHz = 900 MHz

P_t = Peak transmitter power = 6.25 W

G_t = Gain of transmit antenna = 4 dBi = 2.5

7.5 Field Experiment Special Precautions

The following operations shall be followed during the field experiment.

- Frequency authorization for the UWB SIRE radar will be obtained from the host activity frequency manager.
- Personnel with medical electronic devices shall avoid the area directly in front of the transmit antennas while the UWB SIRE radar is operational.
- Personnel shall maintain a minimum safe distance of 20 ft while the Expedition is moving.
- The verbal emergency UWB SIRE radar shutdown statement will be “Cut Transmitter.” The visual emergency UWB SIRE radar shutdown signal will be an open hand moving horizontally across the throat.
- Only those personnel necessary to accomplish the required field preparation and/or experiment shall be permitted in the area during operations.
- No UWB SIRE radar transmission during Expedition fueling.
- Drip pans/cans will be placed under leaks if necessary.
- Oil and fuel spills shall be cleaned up in a timely manner.
- Equipment such as forklifts, umbilical connections (air cooling, electric, hydraulic, etc.), and yellow gear systems (backhoe) are to be operated by experienced personnel.
- The general area will be inspected daily for any flammable material and liquids. If such material is found, the field experiment will be delayed until the material is removed.
- If fire occurs, the Host Activity Fire Department will be notified.
- At least one fire extinguisher will be stored in the vehicle during the field experiment.

8. Operational Security

All aspects of the UWB SIRE Radar Upgrade Assessment Experiment are UNCLASSIFIED; therefore, an Operations Security (OPSEC) Annex is not required.

9. Management

The schedule and milestones are depicted in table 6.

Table 6. UWB SIRE radar upgrade assessment field experiment schedule.

Event	Time (Hours)
Radar set-up and checkout (phase I).	8.0
Placement of target set arrangement.	1.0
GPS survey, digital documentation, and soil measurements.	1.5
Data collection forward-looking, VV polarization.	1.0
Convert from VV polarization to HH polarization.	0.5
Data collection forward-looking, HH polarization.	1.0
Convert from forward-looking to side-looking.	0.5
Data collection side-looking, HH polarization.	1.0
Convert from HH polarization to VV polarization.	0.5
Data collection side-looking, VV polarization.	1.0
Data Analysis (3 hrs/1000 m data run x 8 data runs).	24.0
Augmented Reality data run (2.0 hrs/look configuration x 2 configurations).	4.0
Radar break-down and pack-up.	4.0
Trihedral retrieval.	0.5
TOTAL	**48.5**

9.1 Roles and Responsibilities

9.1.1 ARL Lead

This person is responsible for all direct contact with the host activity before, during, and after the UWB SIRE radar upgrade field experiment. Roles and responsibilities include, but are not limited to (a) generating the experiment plan, Safety Operating Procedure (SOP), and CERDEC Safety Checklist; (b) coordinating host activity; (c) coordinating targets for experiment; (d) ensuring paperwork is submitted (SOP, CERDEC Safety Checklist, DD-1494, etc.) and

authorization received; (e) conducting site surveys and selection of areas for experiment sites; and (f) ensuring all team members are briefed on their roles and responsibilities.

9.1.2 UWB SIRE Radar Operator

This person is responsible for radar operation. Roles and responsibilities include but are not limited to: (a) operation of the radar, (b) recording data run information, (c) orchestrating data collection, and (d) maintaining experiment tempo.

9.1.3 Target QA

This person is responsible for ensuring the targets are prepared as defined in the experiment plan. Roles and responsibilities include but are not limited to: (a) verifying proper placement (location and orientation) of targets, (b) monitoring GPS surveys, and (c) verifying digital documentation of targets and target set arrangement.

9.1.4 Radar Assembly

This person is responsible for ensuring the radar and all support systems are properly assembled and integrated. Roles and responsibilities include assembling the (a) radar, (b) Augmented Reality system, (c) radar and data analysis computers, (d) antenna mount assembly, (e) antenna array assembly, and (f) verifying proper operation of the entire UWB SIRE radar system.

9.1.5 Data Analysis

This person is responsible for processing the UWB radar raw data and forming images, as well as superimposing both UWB radar and satellite map imagery onto the COTS digital video camera imagery.

10. References

1. Federal Communications Commission Office of Engineering and Technology, “Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields’, OET Bulletin 65, August 1997.
2. DA Pamphlet 385-64, Table 6-4 (Safe Separation Distance Equations Using Unshielded Munitions), dated 15 Sept 99.

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Appendix A. Hazard Analysis

HAZARD ANALYSIS

HAZARD	**CAUSE**	**EFFECT**	**HAZARD LEVEL/ RISK**	**PREVENTATIVE MEASURES**	CORRECTIVE ACTION
Inadvertent Detonation of UXO.	Unknown UXO buried in area.	Loss of life.	I/D	A dig permit will be obtained to reduce chance of digging in previous ordnance range.	Halt dig and notify safety and explosive personnel if UXO discovered.
Radio Frequency Hazard to Personnel	Personnel present in hazard area during UWB SIRE radar transmissions.	Bodily injury due to electromagnetic radiation.	IV/D	The UWB SIRE radar is not a safety hazard to personnel. The system is not capable of exceeding general population/ uncontrolled area power densities.	Not applicable.
Radio Frequency Hazard to Fuel	Ignition of fuel vapors due to UWB transmissions.	Loss of radar and life.	IV/D	The UWB SIRE radar will not be transmitting during fueling.	Not applicable.
Personnel Experience Heat Exhaustion	Temperatures at YPG in Jul-Aug timeframe exceed 110 degrees.	Bodily injury due to overheating.	II/C	Air-conditioned Connex containers will be provided at test sites. Water will be provided. Team members will monitor each other throughout the day for signs of dehydration.	Seek medical attention for the affected person(s). Notify safety personnel.

HAZARD LEVEL:

Severity:
- I. Catastrophic. May cause death and/or major equipment damage.
- II. Critical. May cause severe injury or major equipment damage.
- III. Marginal. May cause minor injury.
- IV. Negligible. Will not result in injury or equipment damage.

Probability:
- A. Frequently. Likely to occur immediately or within a short period of time.
- B. Probable. Probably will occur in time.
- C. Occasional. May occur in time.
- D. Remote. Not likely to occur.

List of Symbols, Abbreviations, and Acronyms

A/D	Analog to Digital
AGL	Above Ground Level
ARL	U.S. Army Research Laboratory
BIT	Built-In Test
COTS	Commercial-Off-The-Shelf
CERDEC	Communications-Electronics Research, Development, and Engineering Center
DGPS	Differential Global Positioning System
EME	Electromagnetic Environment
ERR	Experiment Readiness Review
FPGA	Field Programmable Gate Array
HH	Horizontal Receive Horizontal Transmit
IED	Improvised Explosive Device
INS	Inertial Navigation System
MPE	Maximum Permissible Exposure
OPSEC	Operations Security
PC	Personal Computer
PEL	Permissible Exposure Limit
RF	Radio Frequency
SAR	Synthetic Aperture Radar
SEDD	Sensors and Electron Devices Directorate
SIRE	Synchronous Impulse Reconstruction
SM	spectrum management
SOP	Safety Operating Procedure
TEM	Transverse Electromagnetic

T/H	Track and Hold
UWB	Ultra Wideband
UXO	Unexploded Ordnance
VME	Versa Module Europa
VV	Vertical Receive Vertical Transmit
WS	Workstation

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TOTAL:	26 (24 HCS, 1 CD, 1 ELECT)

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